OPTIONAL FORM NO. 10

UNITED STATES GOV. .NMENT

Memorandum

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25X1 TO : [redacted] OSA

DATE: 23 June 1965

25X1 FROM : [redacted] PC/ORD

SUBJECT: Boron Filament Research

This memo on Boron Filament Research summarizes a study by [redacted] PC/ORD. PC is not pursuing any developmental objectives at this time, but we are attempting to stay current with technological advanced. We shall be happy to discuss the technical aspects of this work in detail, if you wish. 25X1

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ORD-723-65

15 March 1965

MEMORANDUM FOR FILE

SUBJECT: Boron Filament Research

1. Purpose: This memo has three objectives:

a. To comment on the importance of materials research as a limiting factor in defense planning.

b. To place boron filament research in perspective with regard to the overall trend of materials research.

c. To consider specific characteristics of boron and indicate their advantages and disadvantages in fulfilling present and future materials requirements.

2. Conclusions:

a. Structural and skin materials currently may be regarded as the principal limiting factor in the manufacture of high speed combat aircraft (>Mach 2.2). The development of the next generation of aircraft will require materials having 2 - 3 times the modulus of elasticity, strength, and temperature of current materials. In missiles, the use of projected boron composites could cause significant cost reduction and payload (23%)/ or range increases.

b. Boron filaments are currently the most promising candidate in this country for use in composites over the next 5 - 8 year period primarily because they retain their properties for long periods of time up to 1700°F. Research on special glasses and beryllium will be continued but metal whiskers appear to have the greatest long range (i.e. 20 year) potential. The research paths toward "tailored" materials will be diverse in world-wide perspective since local technological know-how will exercise a major role in the selection of materials. Consequently, no single plateau of accomplishment can presently be defined for intelligence targetting.

c. Boron filaments have been produced which exceed all the minimum materials specification for the next generation of aircraft and missiles. However, the concurrent development of high temperature binders, reduction of cost, and great increases in production rate will be necessary for widespread utilization.

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3. Background: Recently the Air Force completed Project FORECAST which set forth their research objectives through 1975. Foremost on their list was the development of boron filaments which General Schriever, Chief, AFSC, described as the "greatest materials advance in three thousand years". Such a strong statement seems to warrant a deeper investigation by ORD personnel to determine to what degree the next generation of military aircraft are limited by the current state-of-the-art in materials technology and to ascertain if a specific technological plateau could be defined which could be targeted against successfully if anticipated sufficiently far in advance. Consequently, three steps were taken:

a. Contact was made with Dr. Lovelace who is Technical Director, AF Materials Lab., Wright-Patterson Field under whose auspices the current boron program program is directed. Dr. Lovelace cooperated fully in arranging discussions with AF and contractor scientist and made available many technical reports.

b. Contact was made with Dr. Earl Hayes, AD (Materials), DDR&E, whose responsibility it is to approve and direct all materials research within DOD. Dr. Hayes was most candid and helpful in placing the boron program in perspective.

c. Finally, OSI, ORR, FMSAC, and ONE Personnel were contacted to determine the current level of CIA interest in foreign materials research and to relate possible applications to intelligence priorities.

4. Perspective: Materials research today is undergoing a period of rapid transition. In combat aircraft, new high temperature materials are required for skin, structural, and engine parts before adequate utilization can be made of current design capabilities. For example, the next generation of combat aircraft requires materials with tensile strengths in excess of 300,000 psi, a modulus of elasticity (stiffness) of 20 million psi which will retain their characteristics between 600 and 1100°F. By contrast, current materials only have tensile strengths of 70,000 psi and have a modulus of 9 million psi. Furthermore, even these specifications must be greatly reduced above 300°F. Translated into functional terms: the large scale production of aircraft capable of exceeding mach 2.2 is limited by materials. In missiles, the picture is somewhat different: weight tradeoffs are manifested in reduced mission capabilities and increased cost. All these factors have contributed to an intensive search for new and better materials. For example:

a. Glass research has progressed in the past five years. Speccial glasses have been developed with tensile strengths of 500,000 psi and a modulus of elasticity of 60 million psi. Problem: strength retention drops off rapidly above 400°F.

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b. Beryllium research has likewise made great progress and filaments having a modulus of 40 million psi with 80,000 psi tensile strength are quite attractive. Problem: limited beryllium supplies will keep the cost effectiveness well above acceptable limits.

c. Metallic whiskers promise to be the solution of the 1980's and 1990's but most certainly will not be available for use in the next generation of aircraft or missiles.

Where does this leave us? Dr. Hayes suggested that the next 5 to 10 years will be spent on composite design and fabrication so that the best features of presently available materials will be combined in response to the demands of a "transition generation" of aircraft and missiles. The true fulfillment of the coming materials age will probably yield "tailored" materials. In the meantime, the US, its allies, and its adversaries will probably follow many different paths in order to exploit local technological know-how. From the viewpoint of intelligence collection, the path is too unpredictable to define a single plateau for targeting.

5. Why boron? Because of the nature of the metallic bond, its strength varies only within narrow limits. By contrast, while the mechanisms governing the elastic modulus are less well understood, it is known that it varies over a much wider range; consequently, when one studies the properties of elements and learns that boron has an extremely high modulus of elasticity as well as acceptable strength it causes one to consider it very seriously as a potential filament material, especially since it is light and consequently provides an unusually high specific stiffness and strength. A general survey of boron characteristics is as follows:

a. Low density (15% lighter than aluminum)
b. Extreme hardness (9.2 on moh's hardness scale)
c. Good strength retention up to 1800°F.
d. Very high modulus of elasticity (60 million psi)
e. Very high modulus to density ratio (7.05×10^8 in)
f. Very high tensile strength (greater than 500,000 psi)
g. High radar absorption

In brief, boron has many characteristics which appear to exceed the minimum AF requirements for the next generation of aircraft, the principle one being its adaptability to a high temperature environment.

4. Problems: The strong points nominate boron as the leading candidate for making an early contribution to composite technology. On the other hand, a number of obstacles must be surmounted before a material is actually fielded. For example:

a. Production rate is currently very slow (40'min.) since a vapor deposition process is used in which boron trichloride is decomposed and boron is deposited on a tungsten substrate. If large scale production is ever to be commenced, an alternate process such as drawing through a melt will probably have to be perfected to permit production rate of several thousand feet per minute.

b. Production cost is still in excess of $150 per pound largely because the tungsten wire substrate costs approximately $70 / pound. It is anticipated that silica substrates will be used in the near future thus substantially reducing cost. If a total cost of $30 / pound could be attained widespread application would result.

c. c. Finally, and perhaps most important, high temperature binders must be developed to utilize the inherent advantages of the material. Intensive work in this area is currently being conducted.

6. <u>Applications and Cost Effectiveness</u>: Great caution must be used when projecting a substance currently in the research phase beyond the development phase into the field of competitive hardware. To date, boron filaments having strengths as high as 1 million psi and modulii of elasticity of 60 million psi have been produced in the laboratory. The current average tensile strength is approximately 350,000 psi. For the purpose of their projections, the AF assumes 750,000 psi filament strength which is not unreasonable and could probably be defended. Using these figures they estimate that the weight of a direct lift engine could be reduced 29%, cruise turbojets engines by 26%, VTOL's 27%, strategic transports 30%, 3-stage solid ICBM's 24%, and 2-stage ICBM's 19%. High altitude reconnaissance aircraft could benefit greatly from improved materials; for example, the AF estimated the range of the A-11 could be increased 40% by propulsion system weight savings of only 15% or its range could be increased by 220%. While the figures may be suspect until the final product is produced never-the-less it provides a good example of the current limitations imposed by present-day materials.

7. <u>The Future</u>: Perhaps one should once again pause and weigh the fact that boron is just one reasonable means to an end. The facts of life dictate that "boron aircraft" will not become a reality for many years if ever, on the other hand, it has already been demonstrated that the incorporation of 2% boron filaments (by weight) into the titanium skin of the A-11 will increase its modulus by 25%. This example perhaps points toward the most likely course of boron filament development, in other words, we will probably see the next generation of aircraft utilizing "reinforced" materials but it will be some time before a sophisticated level is attained in "tailored" materials.

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